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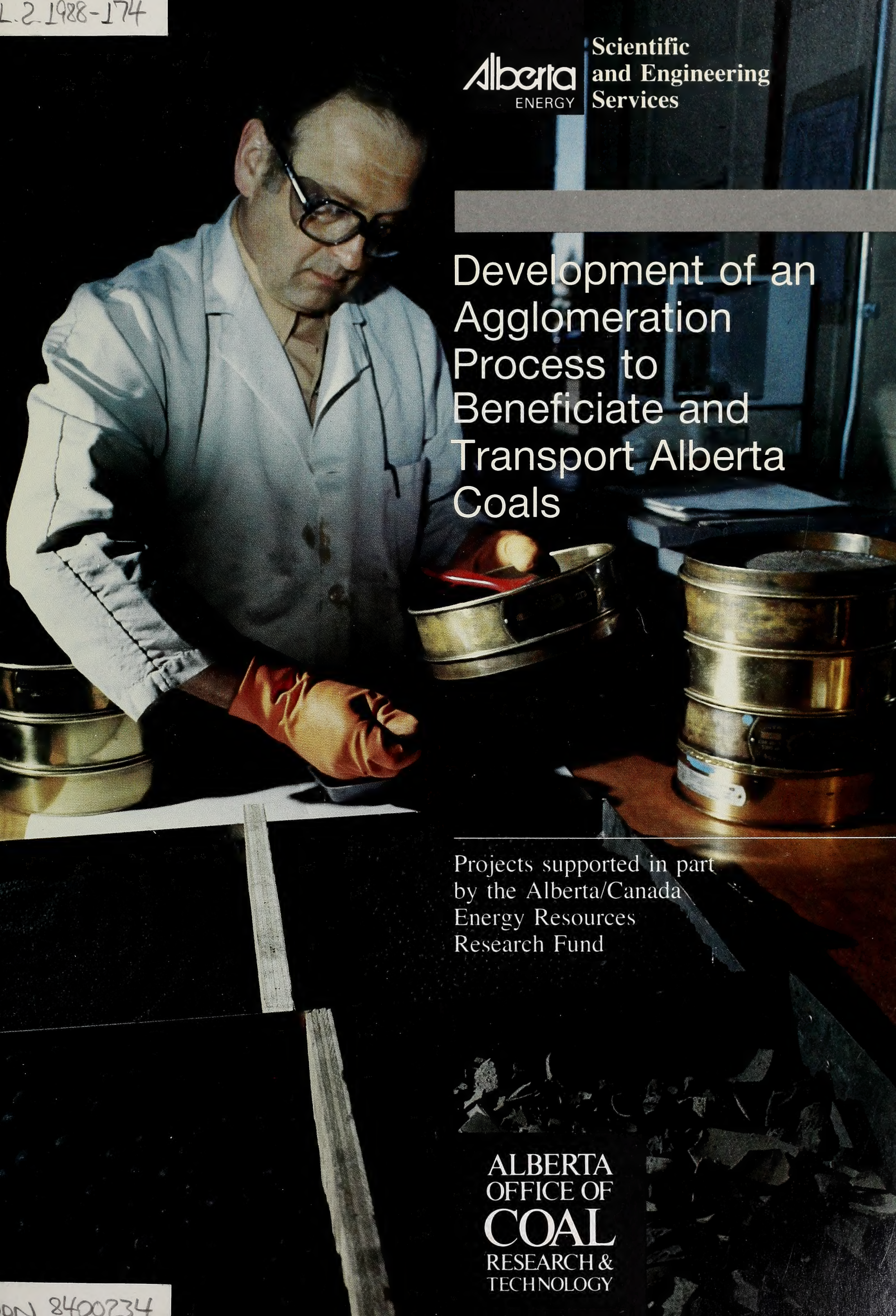

Alberta
ENERGY

Scientific
and Engineering
Services

# Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals

Projects supported in part
by the Alberta/Canada
Energy Resources
Research Fund

ALBERTA
OFFICE OF
COAL
RESEARCH &
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# Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of our resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal and conventional energy resources, as well as energy conservation and renewable energy. Program administration is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In recognition of the importance of coal to Alberta's economy, the Alberta Office of Coal Research and Technology was established in 1984 within Alberta Energy and Natural Resources (now Alberta Energy). Its primary purpose is to encourage the development and application of new technologies related to Alberta coals. The Office provides funding contributions to research and development projects in industry, academic institutions and other research establishments and monitors their progress in an overall program of improving the production, transportation and marketability of Alberta coals.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page 14.

# Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals

Alberta coals are about 200 million years younger than eastern American or European coals. This age difference, along with other factors, is responsible for Alberta coals having less sulphur, but greater mineral content than some other coals. Also, bituminous coals from Alberta are susceptible to mechanical degradation; when they are mined or washed, they will disintegrate and form large amounts of fines (up to 40 per cent).

To overcome these deficiences, various beneficiation and fines recovery processes have been tried over the years with mixed results. However, one process which shows considerable promise involves oil agglomeration of raw coal. This method, which was developed by the Alberta Research Council, not only reduces mineral matter and moisture in the agglomerated coal and allows recovery of fines, but in one configuration it uses pipelines to provide the required mixing and transportation of the resulting agglomerates.

This process, which was developed with financial support from the Alberta/Canada Energy Resources Research Fund (A/CERRF), has been subjected to an economic analysis and has been used to produce sufficient quantities of agglomerated coals to conduct pilot-scale combustion tests.

While Alberta's coal companies would like to sell increasing quantities of bituminous coal in domestic and overseas markets, competition from other suppliers and the advent of new combustion technologies have intensified the need to improve the Alberta product. Preferably, bituminous coals should be beneficiated to reduce their mineral matter content to a maximum of eight per cent. In addition, methods need to be found to avoid the loss of coal fines; transportation costs should be reduced; and the thermal rheological properties of coking coals should be modified to increase plasticity and produce a better coke.

For these reasons, an investigation was launched in 1980 at the University of Alberta, in collaboration with Alberta Research Council researchers, to develop a system of coal beneficiation by agglomeration.

## Hydraulic Mining — Coal Agglomeration — Slurry Transportation

In its initial form, the investigation comprised three components: (1) hydraulic mining; (2) coal agglomeration; and (3) slurry transportation. The concept was seen as having several advantages, particularly for soft coals found in inclined seams. For example:

- hydraulic mining could be twice as productive as the conventional longwall method of mining;
- dust problems could be virtually eliminated and the likelihood of gas explosions could be reduced;
- lower capital and maintenance costs could be expected; and
- hydraulic mining has a respectable safety record.

Subsequently, the hydraulic mining component was dropped from the study; research work funded by A/CERRF concentrated on the remaining two elements.

The agglomeration component of the process was based on studies that had been done at the National Research Council in Ottawa since the 1940s. There, investigations focused on potential applications of dispersed-phase agglomeration of a variety of materials.

In experiments dating from the 1950s, the concept as applied to bituminous coal uses an organic wetting agent dispersed in water that attaches itself to the hydrophobic, desirable elements of finely-divided coal, and rejects the hydrophilic mineral matter. Once the coal particles are coated with the wetting agent, they tend to stick together and form flocs or agglomerates, which can be separated from impurities by screening.

Previous studies showed that coal agglomeration reduces the mineral matter content, and it can be used on coal fines. Furthermore, when oils are used as wetting agents, material handling is easier, and dust explosions on hot charging of coke ovens can be prevented.

While all these benefits represented sufficient reason to implement an agglomeration program in Alberta, the unique aspect of the joint University of Alberta/Alberta Research Council proposal involved the use of a slurry pipeline, which would serve as the reaction vessel, in which agglomeration would take place, and the means by which agglomerates would be transported.

## Experimental Work

Initially, two examples of bituminous coking coals and two examples of bituminous thermal coals (all of which were finely ground to particle sizes less than 0.59 mm) were used in agglomeration tests. Included were several wetting agents: kerosene, diesel oil, Athabasca bitumen, refinery heavy ends and a product of the hydroprocessing of Athabasca bitumen, all having less than 30 per cent aromatic content. Kinetic studies, involving one of the thermal coals, were carried out in batch-scale stirred tanks at room temperature to investigate the effects of various reaction conditions on the growth rate of agglomerates. Conditions that were altered included liquid/solid ratios, viscosity of the wetting agent, stirrer speed and particle size distribution of the feed coal.

In these experiments, it was found that the type of wetting (or bridging) agent was as important as its concentration; the average diameter of agglomerates could be controlled by the bridging agent concentration.

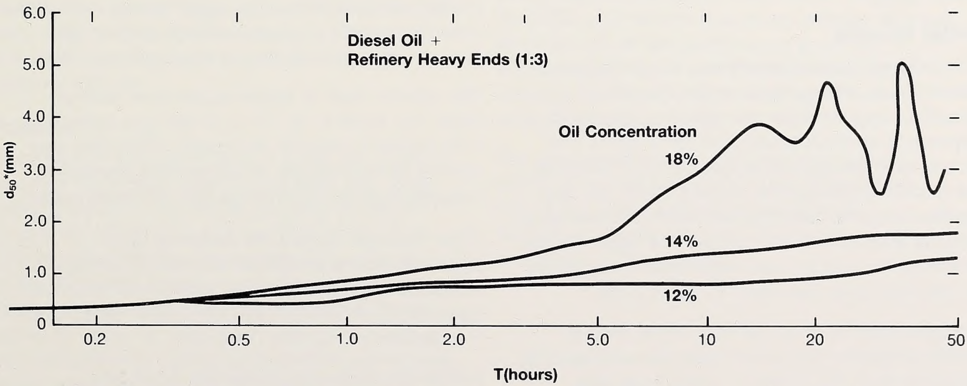
Once the process was better understood, pipeline agglomeration studies began using a 50.8 mm internal diameter, horizontal recirculating pipeline loop. The upper section of the loop was acrylic, while the lower pipe was metal with a transparent horizontal section through which the agglomerates could be observed. A centrifugal pump was used to force slurries through the pipeline.

In the pipeline studies, mixtures of bridging agents were used at concentrations ranging from 14 to 27 per cent by weight of coal. The coal was finely ground; typically, the $d_{50}$ diameter ranged from 0.05 to 0.4 mm for various coal samples. ($d_{50}$ refers to the situation where 50 per cent of the particles are larger and 50 per cent are smaller than the $d_{50}$ diameter.)

Studies performed in the pipeline revealed that four distinct growth phases occur during coal agglomeration:

1. initial stage, when loose flocs are formed;
2. a wetting stage, when the bridging liquid fills the pore spaces in the flocs;
3. a quick growth stage, during which the flocs coalesce; and
4. a stable stage, when the agglomerate size does not change.

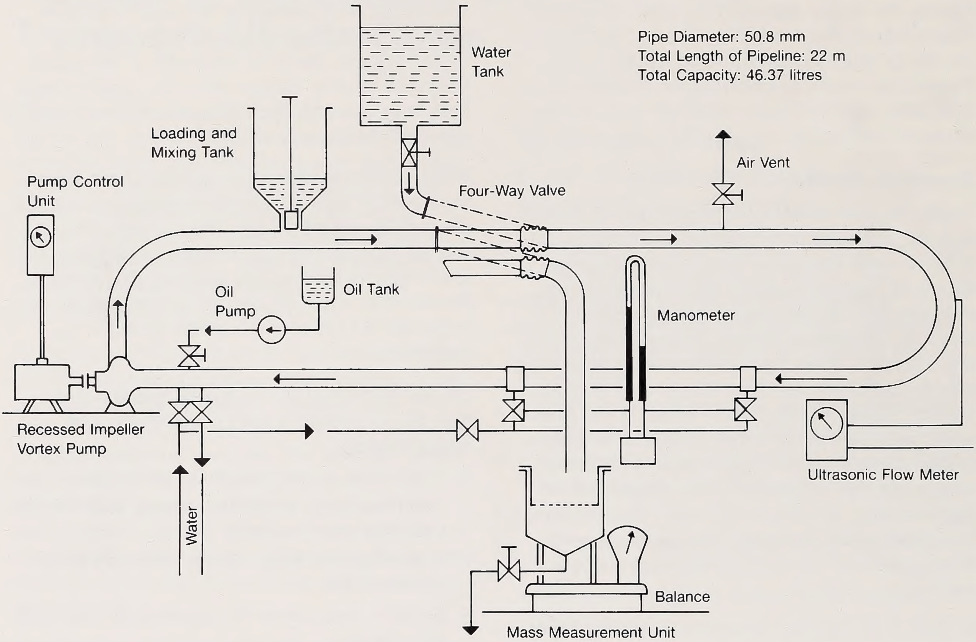
**Influence of Oil Concentration on the Growth of Agglomerates**



*median particle size; 50% by weight of coal particles are smaller than the $d_{50}$ size, and 50% are larger

(Source: *Beneficiation and Transport of the Mined Coal*, Ignasiak, B. and C.M. Rodkiewicz, Alberta Research Council/University of Alberta, September 30, 1983)

**Schematic Diagram of Equipment Used in Pipeline Loop Reactor**



(Source: *Beneficiation and Transport of the Mined Coal*, Ignasiak, B. and C.M. Rodkiewicz, Alberta Research Council/University of Alberta, September 30, 1983)

Under pipeline reaction conditions, the slurry flow changed as the solids increased in size. Three distinct phases were observed, each of which was accompanied by considerable changes in the pipeline pressure.

## Initial Results

The preferred bridging agent was a 1:3 mixture of diesel oil and refinery heavy ends. The rate of growth of agglomerates was found to be strongly dependent on the amount of bridging agent. The growth rate was also influenced by such factors as the method of adding the bridging agent, the size distribution of the feed coal and wetting properties of coal particles. It was also learned that agglomerates produced in pipelines were larger and more uniform in size than those generated in stirred tanks.

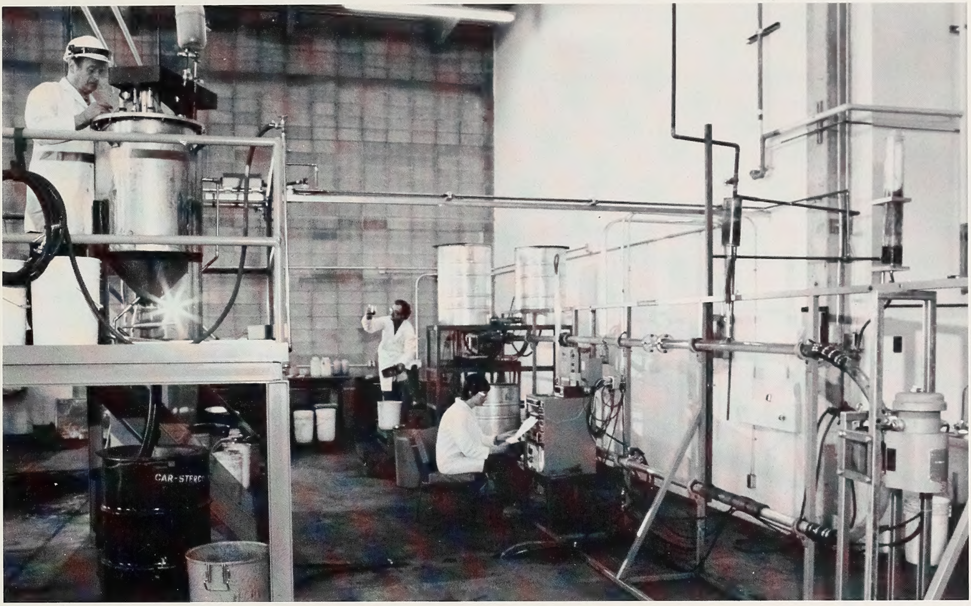
Approximately 35 to 80 per cent of the mineral matter present in the parent coals was eliminated by agglomeration. For instance, coking coals that contained up to 40 per cent mineral matter had only eight to 15 per cent after agglomeration. Similarly, thermal coals, which had as much as 22 per cent mineral matter, were converted into agglomerated products having only five to seven per cent mineral matter. Also, tailings settled faster. They had high ash contents and were essentially free of coal matter.

From 94 to 97 per cent of the dry, ash-free coal matter was contained in the agglomerates, while the moisture content of agglomerates was 30 to 50 per cent lower than for the air-dried, parent coals.

The calorific value of agglomerates from thermal coals was found to be 30 to 40 per cent higher (on a dry matter basis) than the parent coals. This was caused by the inclusion of oily bridging agents in the agglomerates and the rejection of mineral matter.

Other findings included the discovery that agglomerates have sufficient mechanical strength to withstand transportation in a pipeline over distances equivalent to 1 500 to 2 900 km at flow velocities of 1 to 2 m/s.

Inexpensive heavy oil residue and Athabasca bitumen can also be used as wetting agents if admixed with lighter petroleum or bitumen fractions. This is significant, because these petroleum products are abundant in Alberta.



*Pipeline loop used at Alberta Research Council to produce and transport agglomerated coal.*

(Photo courtesy of Alberta Research Council)

## Low-Rank Coal Studies

In 1983, a new series of laboratory studies was begun at the Alberta Research Council, this time focusing on four samples of thermal bituminous coal and five samples of subbituminous coal. As before, agglomeration was carried out in stirred tanks and in a slightly larger diameter pipeline-loop reactor. Coal particle sizes ranged from 0.06 to 2.0 mm, while bridging agents comprised bitumen or emulsified heavy Lloydminster oil admixed with selected light oils.

## Results

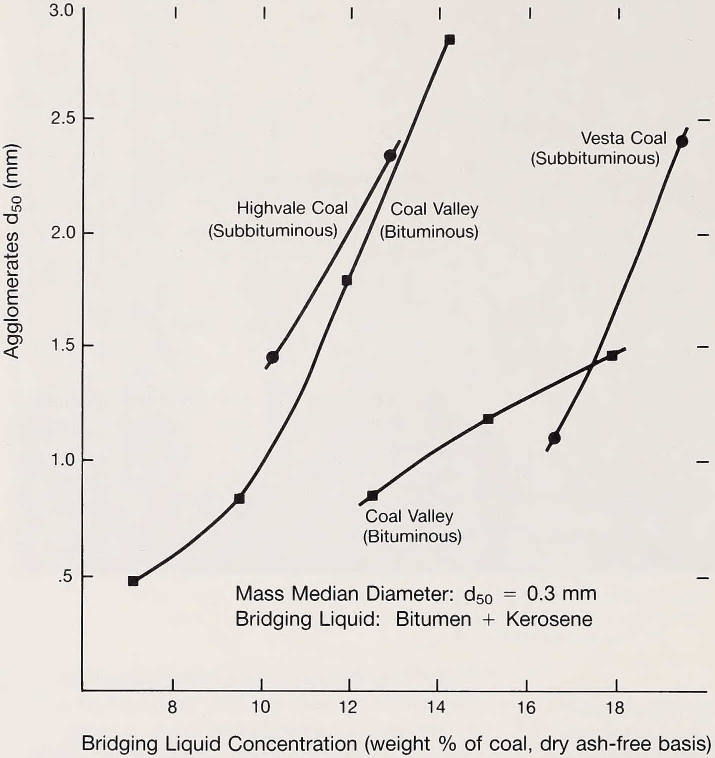
The optimum size distribution of coals was found to be when $d_{50}$ ranged from 0.17 to 0.30 mm, while bridging liquids containing 80 per cent of either bitumen or heavy oil and 20 per cent of selected light oils were effective in agglomerating all of the coals. For subbituminous coals, bitumen-based bridging liquids appeared to be better than those based on heavy oil. Also, each subbituminous coal behaved differently during agglomeration and required alterations in the type of light oil used in the bridging agent; kerosene and diesel oil were the most desirable.

Single-stage application of bridging agents was found to be the most effective; the agglomeration process was completed within five to 10 hours. Attempts at applying bridging agents in two stages resulted in weak agglomerates.

Agglomerates produced from subbituminous coals were steam-heated over a temperature range of 220 to 600°C to determine how much bridging oil could be driven off. At temperatures up to 350°C, approximately 40 per cent of the bridging liquid could be recovered without lowering the calorific value of the agglomerates.

The agglomeration time was shortened in both stirred tanks and the pipeline loop by removing the mineral-laden wastewater as soon as microagglomerates formed. The reaction was completed in clean water.

## The Influence of Bridging Liquid Concentration on Agglomerate Size



(Source: *Pipeline Agglomeration of Coal*, Ignasiak, B., Alberta Research Council, May 1984)

## Properties of Coals, Before and After Agglomeration

| | Run-of-Mine | | | Agglomerates | | | | |
|---|---|---|---|---|---|---|---|---|
| Coals | % Ash | Calorific Value (air dry) BTU/lb. | Calorific Value (air dry) kcal/kg | % Ash | % Oil | % Water | Calorific Value (air dry) BTU/lb. | Calorific Value (air dry) kcal/kg |
| high volatile bituminous (thermal) | 20-48 | 7 500-10 000 | 4 158-5 544 | 5-13 | 10-18 | 6-15 | 11 600-12 500 | 6 431-6 930 |
| subbituminous | 12-30 | 8 600-9 200 | 4 767-5 100 | 7-13 | 12-20 | 7-11 | 11 000-12 000 | 6 098-6 653 |

(Source: *Pipeline Agglomeration of Coal*, Ignasiak, B., Alberta Research Council, May 1984)

### Hydraulics of Coal Agglomerates

A preliminary investigation was made of the hydraulic characteristics of coal agglomerates, keeping in mind the practical applications of agglomerating in a pipeline and then transporting the product to terminals as far away as the west coast of British Columbia, or even further to central Canada.

Using the 50.8 mm diameter pipeline loop, studies were made of the influence of particle diameter, particle size distribution and particle concentration on the pressure drop; changes in transport concentration as a function of velocity; the optimal velocity for the carrier fluid; and the critical deposit velocity.

It was found that an increase in the mean particle size produces significantly higher pressure drops in the pipeline, and pressure losses for raw coal particles are much higher than for agglomerated coal particles of the same diameter and concentration.

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## Economic Feasibility Assessment of Agglomeration Processes

Based on the results of the experimental agglomeration studies performed at the Alberta Research Council, an economic assessment was made of the agglomeration process by Manalta Coal Ltd., assuming the production of 500 000 tonnes a year of agglomerated solids from subbituminous coal at a new mine operation.

By using discounted cash flow analysis, the required price of the agglomerated fuel at the Alberta rail terminal was determined for a base case process; the same analysis was performed for cases involving several alternative options.

Besides assuming a production rate of 500 000 tonnes a year, the base case conditions included:

- use of subbituminous coal, as represented by coal from the Whitewood Mine, having a high ash content (28.9 per cent), including substantial amounts of clay;
- a bridging agent, comprising 80:20 Cold Lake heavy oil:diesel oil, added in amounts corresponding to 16.4 per cent of the coal matter;
- crushing, desliming and comminuting the coal (Whitewood coal could not be agglomerated without desliming);
- two-stage agglomeration in stirred tanks;
- drying and de-oiling of agglomerates by superheated steam produced in a conventional, gas-fired boiler. (Experimentally, agglomerates could be dried to two per cent total moisture, but they subsequently absorbed enough moisture to achieve equilibrium with the environment; saturation occurred at 12 to 15 per cent moisture.) It was assumed the oil is recovered for re-use as a bridging agent, with any excess sold at fair market prices; and
- eight per cent coal loss during desliming and two per cent loss of oil in tailings from agglomeration.

Following economic assessment of the base case, sensitivity analyses were performed to measure the effects of varying:

- the scale of the operation (from one-half to twice the size of the base case);
- hydrocarbon price levels;
- the value of recovered hydrocarbons;
- the amount of recovered hydrocarbons (50 per cent more or 50 per cent less than the base case);
- the oil content of agglomerates; and
- the prevailing discount rate (plus or minus one-third of the base case).

Also, the following alternatives to the base case were examined:

- using a different coal (subbituminous coal from the Montgomery Mine, which is a lower rank coal having higher moisture and lower ash contents, but is readily agglomerated without need for desliming);
- using different grinding equipment;
- using flotation to separate coal from ash at an early stage in the process; and
- eliminating the oil recovery process.

## Results

The capital cost for a mine and an agglomeration plant operating under base case conditions was estimated at $70 million, with annual operating costs of $50 million. This is equivalent to approximately $100 a tonne of agglomerated product, assuming a 15 per cent return on investment and a 27-year plant life.

The capital costs of the oil recovery unit represented 34 per cent of the total, while natural gas used in the de-oiling and drying operation accounted for the largest portion of the operating costs (13 per cent). The value of recovered oil was found to be approximately the same as the cost of purchasing heavy oil.

From the sensitivity analyses, it was learned that doubling the plant size should lower the annual operating costs by 11.5 per cent; decreasing the return on investment from 15 to 10 per cent should lower operating costs by 13 per cent. On the other hand, costs were not affected to any degree by oil-related factors such as world oil prices, prices paid for recovered oil, the oil content of the agglomerates and the oil recovery level.

When various process components were altered, such as the method of grinding, costs were affected only slightly. However, when oil recovery was eliminated, capital costs and costs per tonne were reduced to $40 million and $75, respectively. It was noted, however, that agglomerates produced in this fashion may require conditioning or treatment before handling or transportation.

The analyses also showed that if desliming could be eliminated (which was not practical when using Whitewood Mine coal), capital costs could be reduced by approximately $5 million to $65 million and the operating cost per tonne could drop from $100 to $92.

This led to an examination of Montgomery Mine coal in a process not using desliming, because this preparation stage was found to be unnecessary with this particular coal. The result was an $8 million drop in the capital cost versus the base case conditions, and a per tonne cost of $84.

The most encouraging results arose when Montgomery Mine coal was used without desliming and oil recovery, and only two per cent bridging agent was used versus 16.4 per cent in the base case. These conditions lowered capital costs to $39 million, and reduced per tonne costs to only $59, or $41 a tonne less than the base case.

The study produced the following conclusions:

- the effectiveness of agglomeration varies from one coal to another;
- oil recovery is not practical if purchased energy is used;
- one way to help offset the costs of oil recovery would be to recover the sensible heat of agglomeration by using hot agglomerates to heat a gas stream; for example, the combustion air. This assumes, however, that agglomerates are not susceptible to auto-oxidation; and
- lowering the amount of bridging agent used in the process is worthy of further study to define the chemical costs and determine the stability of agglomerates.

## Combustion of Agglomerated Coal

One-tonne samples of a subbituminous coal from the Paintearth Mine, and a high volatile bituminous coal from Coal Valley, were separately ground, mixed and agglomerated by General Comminution Inc. of Toronto, Ontario. A Szego mill was used into which crushed coal, a 4:1 mixture of Alberta heavy crude oil and #2 furnace oil, and water were fed. The resulting slurry of agglomerates was discharged onto a screen to separate mineral matter and water from the agglomerated solids.

The agglomerated products were then air dried and heat treated by Ontario Research Foundation in Mississauga, Ontario. Agglomerates from both types of coal were divided into two samples and heated at two separate temperatures; the bituminous agglomerates were run at 280°C or 375°C, while the subbituminous samples were treated at 280°C or 350°C. Samples from the four treatment runs were stored for subsequent pilot-scale combustion testing, while a portion of each was set aside for laboratory investigations.

Initially, it was intended that all four of the samples would be burn tested, but three of them were accidentally mixed together in preparation for the burn tests and had to be excluded.

The sole remaining sample, an agglomerated product made from subbituminous coal and heat treated to 280°C, was evaluated at the 620 megajoule an hour (MJ/h) combustion research facility of Ontario Hydro. The combustion characteristics of this material were compared with a standard, eastern U.S. bituminous coal known to possess combustion properties suitable for Ontario Hydro's power generation plants.

### Proximate and Ultimate Analysis and Particle Size Distribution of Coals

**Proximate Analysis, g/kg**

| | Standard, Eastern U.S. Bituminous Coal | Agglomerated Subbituminous Coal |
|---|---|---|
| Moisture | 14 | 16 |
| Ash | 80 | 69 |
| Volatile Matter | 357 | 455 |
| Fixed Carbon | 548 | 476 |

**Ultimate Analysis, g/kg (moisture free)**

| | Standard, Eastern U.S. Bituminous Coal | Agglomerated Subbituminous Coal |
|---|---|---|
| C | 756 | 679 |
| H | 57 | 51 |
| N | 16 | 9 |
| S | 17 | 9.8 |
| O | 74 | 177 |
| Ash | 80 | 69 |
| Heating Value, MJ/kg | 32.3 | 28.3 |

**Particle Size Distribution**

| Sieve Opening µm | Standard, Eastern U.S. Bituminous Coal | Agglomerated Subbituminous Coal |
|---|---|---|
| | Cumulative % Undersize | |
| 150 | 100 | 99 |
| 106 | 93 | 92 |
| 75 | 73 | 70 |
| 63 | 59 | 26 |
| 53 | 56 | 16 |
| 45 | 51 | 15 |
| <44 | – | – |

(Source: *Combustibility Evaluation of a Western Canadian Beneficiated Coal Sample*, Mozes, M.S., R. Mangal, R. Thampi and D. Tubman, Ontario Hydro Research Division Report No. 86-232-P, October 15, 1986)

The U.S. coal and the agglomerated subbituminous product were fired at approximately 464 MJ/h into a furnace having top section flame temperatures ranging from 1 268 to 1 300°C.

## Results

In comparison with the U.S. standard, the combustibility of the agglomerated sample was rated as excellent; carbon burnout was 99.7 per cent, versus 98.8 per cent for the standard. The reduced amount of char from the agglomerated sample was attributed to its high volatile matter content (455 g/kg), versus 357 g/kg for the standard.

The following observations were also made:

- visual inspection indicated that the flame from the agglomerated sample was less stable than from the standard. It was concluded this could be caused, in part, by irregular feeding of the agglomerated coal into the furnace;
- $SO_2$ emission levels (1 070 ppm) were lower for the agglomerated coal than for the standard (1 375 ppm). This was expected because the sulphur content of the U.S. coal, at 1.7 per cent, was nearly twice that of the agglomerated coal (0.98 per cent);
- $NO_x$ emission levels were similar; 478 ppm for the agglomerated coal, versus 508 ppm for the standard;
- ash resistivities at 140°C were $2.7 \times 10^7$ ohm-cm for the standard coal, and $3.4 \times 10^6$ ohm-cm for the agglomerated coal. This should not cause any difficulties in electrostatic precipitators;
- the ash fusion temperature of the agglomerated coal was low. It resulted in easily removable soft deposits on the furnace walls. No slagging was observed.

### Gaseous Emissions and Ash Collection

| **Flue Gas Composition**[a] | **Standard, Eastern U.S. Bituminous Coal** | **Agglomerated Subbituminous Coal** |
|---|---|---|
| % $CO_2$ | 14.1 | 15.3 |
| % $O_2$ | 5.0 | 5.0 |
| ppm CO | 140 | 116 |
| ppm $SO_2$ | 1375 | 1070 |
| ppm $NO_x$ | 508 | 478 |
| **Sulphur emission**[b] | | |
| g S/MJ | 0.62 | 0.44 |
| (lb.S/$10^6$ BTU) | (1.4) | (1.0) |
| **$NO_x$ emission** | | |
| g $NO_x$/MJ | 0.21 | 0.19 |
| (lb.$NO_x$/$10^6$ BTU) | (0.5) | (0.44) |
| **Ash Resistivity at 140°C** | | |
| ohm-cm | $2.7 \times 10^7$ | $3.4 \times 10^6$ |
| **Electrostatic Precipitator Efficiency** | | |
| (SCA = 8.3 $m^2/m^3/s$)[c] | 85 | 75 |

[a] normalized to 5% $O_2$

[b] on the basis of coal analysis, calculated sulphur emissions are:
Standard Coal = 0.53 g S/MJ (1.2 lb. S/$10^6$ BTU)
Agglomerated Coal = 0.35 g S/MJ (0.8 lb. S/$10^6$ BTU)

[c] because of sparking observed in the ESP, these measurements are not accurate

(Source: *Combustibility Evaluation of a Western Canadian Beneficiated Coal Sample,* Mozes, M.S., R. Mangal, R. Thampi and D. Tubman, Ontario Hydro Research Division Report No. 8-232-P, October 15, 1986.)

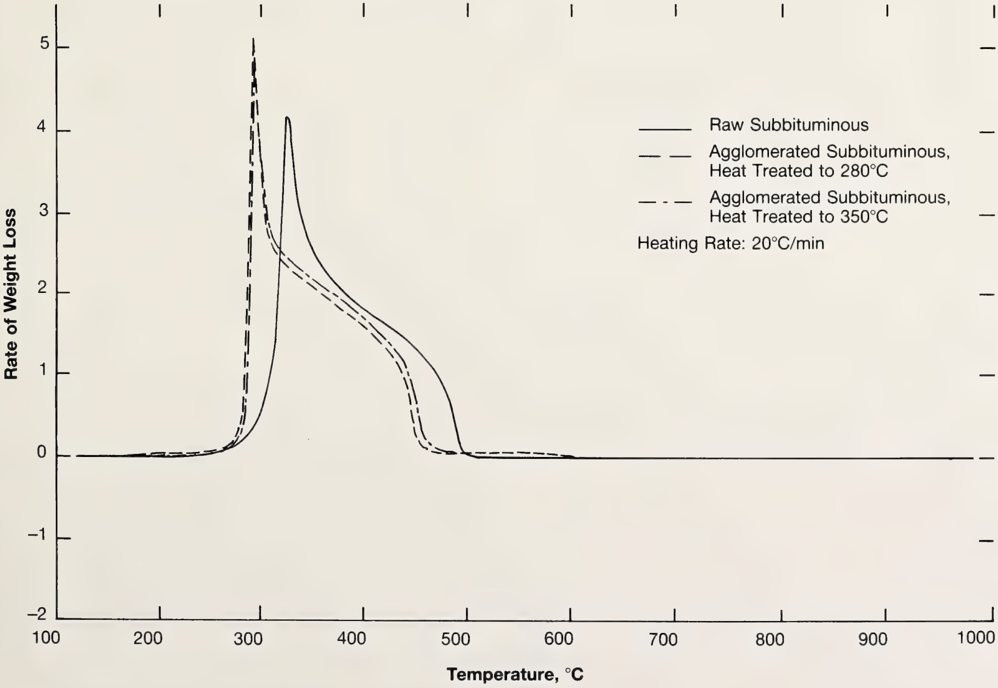
## Combustibility Characteristics of Alberta Coal Agglomerates

| Coal | Preparation | Calorific[a] Value (kJ/kg) | Flammability Index (°C) | Ash (%) |
|---|---|---|---|---|
| Alberta subbituminous | raw coal | 24 000 | 433 | 8.2 |
| | agglomerated + oil recovery to 280°C | 27 400 | 392 | 7.0 |
| | agglomerated + oil recovery to 350°C | 27 200 | 391 | 7.0 |
| Alberta high-volatile bituminous | raw coal | 25 000 | 461 | 11.8 |
| | agglomerated + oil recovery to 280°C | 29 400 | 465 | 6.7 |
| | agglomerated + oil recovery to 375°C | 28 700 | 447 | 8.6 |
| U.S. high-volatile bituminous | raw coal | 31 000 | 398 | 8.3 |

[a] as received

(Source: *Comparative Evaluation of the Combustibility of Alberta Coal Agglomerates*, Knill, K.J., D.E. Ungarian and A.K. Chambers, Alberta Research Council, March 1987)

## Thermogravimetric Analysis



(Source: *Comparative Evaluation of the Combustibility of Alberta Coal Agglomerates*, Knill, K.J., D.E. Ungarian and A.K. Chambers, Alberta Research Council, March 1987)

### Laboratory Combustibility Tests

At the Alberta Research Council, measurements were made on the samples of the four heat-treated and agglomerated coals, as well as on their parent coals and a bituminous coal originating in the U.S., which was representative of coal being imported by Ontario Hydro.

Comparisons among the coals were based on: (1) thermogravimetric analysis; (2) ignition analysis; and (3) entrained flow combustion tests.

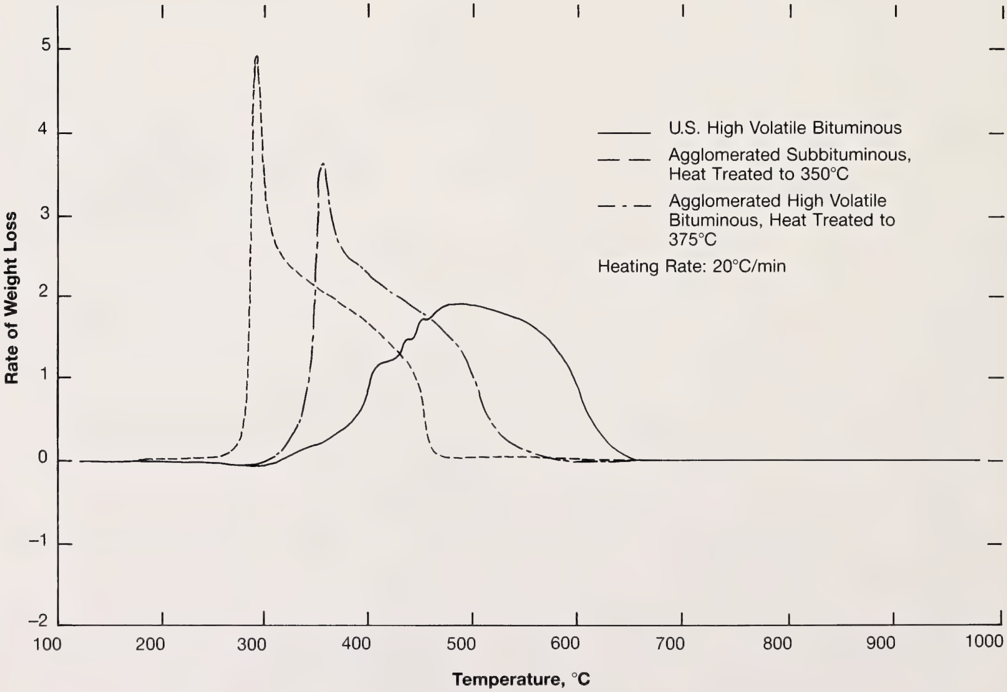
The test results showed that agglomeration, followed by heat treatment to recover some of the bridging oil, improves the calorific value and lowers the ash content of coal. It was also observed that recovery of oil from agglomerates appears to affect combustion characteristics, but the subbituminous coal and its agglomerates burned more rapidly than the U.S. bituminous coal.

## Conclusions

Coal agglomeration not only improves the calorific value and reduces both the ash and moisture contents of Alberta coals, but it provides a method of fully using coal fines, which represents a substantial benefit. Agglomerates exhibit high mechanical strength and superior burning characteristics, which suggests that Alberta's extensive reserves of subbituminous coals could be beneficiated to suit the requirements of overseas markets. The Manalta study indicated, however, that process economics require further investigation.

Some aspects of the studies at the Alberta Research Council, particularly those involving the use of bitumen or heavy oils as bridging agents, are sufficiently unique to have resulted in two patent applications in Canada and the United States.

**Thermogravimetric Analysis**



(Source: *Comparative Evaluation of the Combustibility of Alberta Coal Agglomerates*, Knill, K.J., D.E. Ungarian and A.K. Chambers, Alberta Research Council, March 1987)

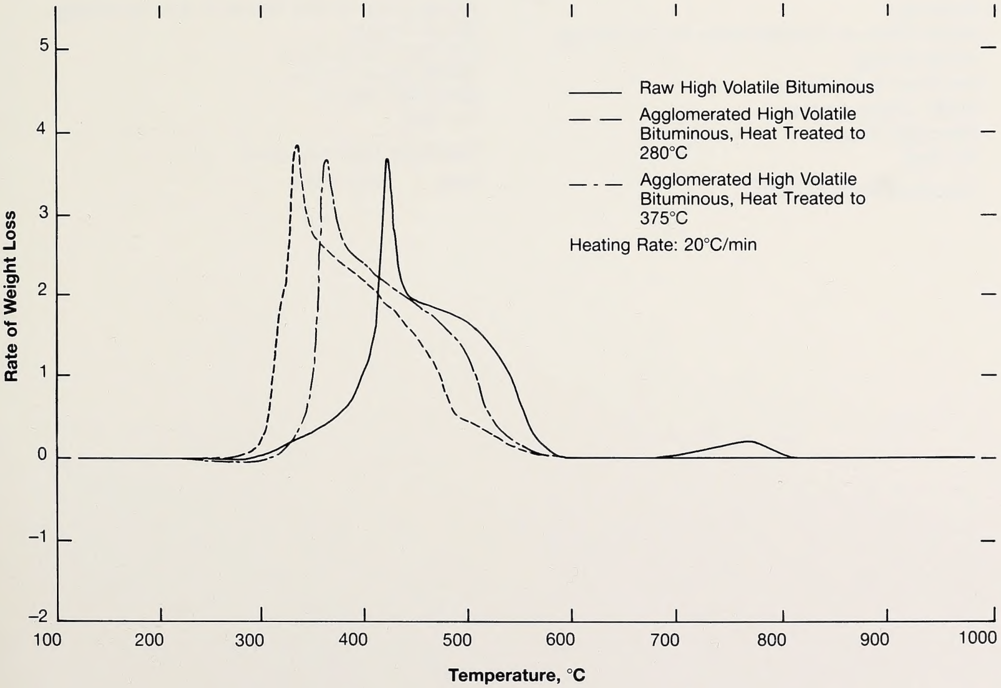
## Further Developments

On behalf of several Canadian oil firms, coal companies, provincial governments and utility companies, as well as American utility companies, state and federal governments and the Electric Power Research Institute, investigators at the Alberta Research Council are continuing to develop a variety of applications for the agglomeration process. Some work has reached the pilot-plant stage.

While some studies are focusing on the production and heat treatment of agglomerates from subbituminous coals, using bitumen or various heavy oils, the method has also been adapted to remove up to 90 per cent of pyritic sulphur from bituminous coals.

As well, the process is being investigated as a method of cleaning up industrial wastes in Alberta and elsewhere. The greatest potential identified so far is in tar pit cleanup in the U.S.

**Thermogravimetric Analysis**



(Source: *Comparative Evaluation of the Combustibility of Alberta Coal Agglomerates*, Knill, K.J., D.E. Ungarian and A.K. Chambers, Alberta Research Council, March 1987)

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